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CHAPTER 1. STORM WATER DRAINAGE PRINCIPLES

CONTENTS

Section Page DP-

DRAFT

1.0 OVERVIEW

In 2004, the Vision 20/20 Water Quality Planning Group recognized the role that sound storm water design principles and practices play in defining the quality of life for southwest Missouri. Sound storm water design practices help to maintain compatible drainage systems, minimize disturbance to existing drainage patterns, control flooding of property, structures, and roadways for design flood events, and minimize environmental impacts of storm water runoff. Storm water systems should be designed both to provide adequate surface drainage and to meet other important storm water management goals, such as protection of water quality, stream channels, habitat, and groundwater. Above all else, storm water management practices must strive to preserve and promote the general health, safety, and welfare of the public. Storm water drainage is defined by watershed, not by governmental jurisdiction, and therefore requires cooperative efforts on a watershed basis to be implemented effectively. This chapter summarizes principles of storm water management, identifies key data sources needed for storm water management, provides an overview of planning approaches, and identifies floodplain management principles.

2.0 PRINCIPLES

Planning and development of urban storm water drainage systems are guided by a set of underlying principles that are based on sound engineering practice and community objectives. Key guiding principles that are the foundation of the design criteria provided in this manual follow.

2.1 Watershed Approach

1. **Storm Water Drainage Does Not Respect Governmental Boundaries and Is Affected by All Who Reside in the Watershed.** The watershed approach to storm water management has been embraced by the U.S. Environmental Protection Agency (USEPA) and many other agencies and communities across the country. Storm water system planning and implementation should include coordination with all affected agencies, communities, and neighborhoods within the watershed. The water resources of a watershed are affected by all who conduct activities within it; therefore, all should be a part of the process of caring for its water resources.

2. **A Storm Water Drainage System Is a Subsystem of the Total Urban Water Resource System**. Storm water system planning and design for any new development must be compatible with watershed master plans and objectives and must be coordinated with plans for land use, open space, transportation, and other community objectives. Watershed master plans must consistently address storm water quantity and quality issues, as well as regional issues.

3. **An Urban Storm Drainage System Should Be Regarded as a Natural Resource That Serves the Community with a Multi-Objective Purpose.** Natural urban drainage systems are a

valuable natural resource in a community and play an important role in its overall quality of life. These areas should be protected and utilized to their full potential in this regard through a multi-objective management strategy that includes flood protection, water quality enhancement, groundwater recharge, preservation of plant and animal habitat, creation of open spaces, protection of natural features and amenities, and provision of recreational opportunities.

2.2 Conveyance and Storage

1. **Flooding Is Primarily a Space Allocation Problem.** The amount of storm water runoff present at any given point in time in an urban watershed cannot be compressed or diminished. Open and enclosed storm systems serve both conveyance and storage functions. If adequate provision is not made for drainage space demands, storm water runoff will conflict with other land uses, resulting in damage to public and private property and the impairment or disruption of other urban systems. In urban watersheds that have been developed without adequate storm water planning, there is generally inadequate space available to construct detention storage facilities to reduce peak flows significantly along major waterways. Creation of adequate space to construct such storage facilities will generally require the removal of valuable existing facilities and is often not economically or socially feasible.

2. **Floodplains Should Be Preserved Wherever Feasible and Practicable to Maintain Naturally Occurring Storm Water Storage.** Nature has claimed and will reclaim a prescriptive easement for floods, via its floodplains, that cannot be denied without significant difficulty and cost. Floodplains serve as natural outfall areas for urban drainage, riparian corridors, and habitat for diverse ecological systems. Encroachment into floodplains should be avoided and should occur only after careful planning and engineering have been conducted so that the effects are fully recognized and minimized. Preservation of urban floodplains provides value to communities through flood hazard reduction, water quality enhancement, stream protection, habitat preservation, open space, linear parks, and recreational opportunities. When determining the width of floodplain to preserve, consideration should be given to the intended use of the floodplain and the dynamic nature of stream channels.

3. **Streams and Riparian Corridors Should Be Maintained As They Naturally Occur to the Maximum Extent Practicable.** Naturally occurring streams and waterways should be preserved in their natural state to the maximum extent practicable by the provision of stream setbacks and the minimization of floodplain filling. Providing buffers between valuable riparian corridors and urban development allows filtering of pollutants from urban runoff before it enters a stream. Consideration should be given to environmentally sensitive stream stabilization in areas where urbanization, altered hydrology, or soil characteristics result in unstable natural channel

conditions. In certain cases, urban hydrologic conditions will require structural stabilization of streams to avoid degradation. These improvements should be completed in an aesthetic and environmentally sensitive manner.

4. **Every Urban Area Has a Minor and a Major Drainage System, Whether or Not They Are Actually Planned or Designed.** Generally, the minor and major drainage systems have distinctly different design criteria based on public health, safety and welfare, and economic considerations. The minor drainage system is typically designed to accommodate moderate flooding. For minor drainage systems, local street flooding resulting from extreme, less frequent rainfall events may be permissible for short periods, as long as public health, safety, and welfare are protected, and structures are protected from inundation. Due to a greater potential threat to public health, safety, and welfare along major waterways, the major system will generally have a higher design standard to minimize the impacts of flooding from more severe, less frequent floods.

5. **Storm Water Drainage Systems Should Not Be Designed to Transfer Problems from One Location to Another.** Urbanization tends to increase downstream peak flows, runoff volumes, and runoff velocities. These changes can cause the capacity of inadequately designed downstream systems to be exceeded and can disrupt natural waterways. The impacts of new urbanization must be reduced through the use of structural and non-structural Best Management Practices (BMPs) that usually include storm water detention. These may be constructed as either on-site or regional facilities based upon watershed master plans developed and maintained by government agencies. Consideration should be given to retrofitting storm water controls as a part of redevelopment projects. Factors to consider include the size of the redevelopment project and its location within the watershed.

6. **Planning and Design of Storm Water Drainage Systems Should Place Public Health, Safety and Welfare, Protection of Property, and Traffic Safety above All Other Considerations.** The primary objective of all storm water drainage design is the protection of public health, safety, and welfare. Storm water systems should be designed to minimize the risk of loss of life. Consideration should be given to the potential for health risks associated with storm water systems and runoff. Designs should minimize the risk of damage to both public and private property and minimize the risk of structure inundation. Streets are commonly used for collection of runoff and are the beginning of the minor drainage system. Streets and the minor drainage system should be designed for the safe and efficient movement of traffic to the maximum extent practicable. Consideration should be given to the benefits that the protection of the environment and water quality have on public health and welfare. Consideration should also be given to the importance of reducing erosion because of the potential for public and private property damage.

7. **The Storm Water Drainage System Should Be Designed for Sustainability and Must Receive Regular Maintenance.** Design of the storm water drainage system should carefully consider the need for accessibility and maintenance to sustain adequate function, whether the facilities will be publicly or privately maintained. The major drainage system is more likely to be maintained by a public entity, whereas the minor system is more often maintained by a private entity. Parts of the major system that serve specific functions for private entities should be maintained by those private entities. Failure to provide proper maintenance reduces both the hydraulic capacity and pollutant removal efficiency of the system. Planning and design of drainage facilities should include consideration of scheduling of work crews and funding necessary to provide proper maintenance.

2.3 Onsite Controls

1. **A Storm Water Drainage System Should Be Designed Beginning with the Point of Discharge, Giving Consideration to Downstream Impacts and the Effects of Offsite Flows.** The location and method of discharge from the site must be determined with great care and in a reasonable manner that does not harm downstream or adjacent property. The engineer should evaluate the conveyance system downstream of each point of discharge from a new development to ensure that it has sufficient capacity to accept design discharges without adverse backwater or downstream impacts such as flooding, stream bank erosion, and sediment deposition. In addition, great care must also be taken in determining the method of acceptance, conveyance, and discharge of storm water runoff flowing across the site and originating from off site.

2. **Design of Storm Water Drainage Systems Should Consider Existing Natural Forms and Features.** Every site contains natural features that characterize and contribute to its natural drainage system. Existing features such as natural drainageways, sinkholes, floodplains, vegetation, soils, geology, and slope affect existing runoff and drainage characteristics. Each development plan should include mapping and careful consideration of these natural features. Storm water system design should preserve and enhance natural features to the maximum extent practicable. A well-designed storm water system will improve the effectiveness of the natural system, rather than negate, replace, or ignore it.

3. **Developments Should Be Designed to Reduce Runoff Rates and Pollutant Loads to Minimize Negative Downstream Impacts to the Maximum Extent Practicable.** Federal and state laws now mandate that most urban areas, including Springfield, monitor water quality and require the application of storm water BMPs to new developments. New impervious areas should be minimized and hydraulically disconnected to achieve maximum contact between runoff and vegetation, thereby maximizing infiltration and filtering of pollutants. Runoff should be routed in a

manner that slows the speed of runoff leaving the site. Where determined to be appropriate, detention basins should be constructed to limit peak flow rates to predevelopment rates. While it is generally not practical to maintain predevelopment runoff volumes, accepted storm water BMPs should be used to the maximum extent practicable to minimize runoff volume.

3.0 DATA COLLECTION

In order to effectively implement sound storm water drainage planning and management practices, the City must develop and maintain a strong base of hydrologic and geographical data. A brief summary of key data requirements follows.

3.1 Rainfall

3.1.1 Purpose. The two primary factors that contribute to the magnitude of a flood are rainfall and runoff response. The characteristics of rainfall that affect the magnitude of a flood are depth, duration, intensity, and location. These characteristics can be quantified for any given storm through the collection of rainfall data. Therefore, an essential component of a community's storm water management program is the establishment of an adequate network of rainfall gauges to provide valuable data when studying rainfall/runoff relationships. The type, number, and location of gauges should be determined based on the area to be monitored, the size and shape of the watersheds of interest, the meteorological and hydrologic characteristics of the community, and the resources available to the governmental agency. Data collected by rain gauges can be supplemented by other sources, such as Doppler Radar data from the National Weather Service. More comprehensive rainfall data can also assist in the analysis of pollutant delivery to the storm water system.

3.1.2 Data Collection Methods. An adequate network of rainfall gauges can collect data both temporally and spatially to allow for quantification of depth, duration, intensity, and location. Generally, rainfall should be collected in time increments ranging from 5 to 15 minutes when being collected for the purpose of flood analysis. Longer time increments may be preferred for long data collection periods more typical of a pollutant load analysis. Spatial distribution of rain gauges should account for the localized nature of thunderstorms, which can be only a few square miles in size and cause severe localized flooding.

3.1.3 Classification of Rainfall. With adequate spatial and temporal rainfall data, the frequency of any particular rainfall event can be classified with the use of accepted Intensity-Duration-Frequency tables found in this manual. It is important to realize that determination of the frequency of a rainfall event does not necessarily translate to the same frequency of the resulting flood event. The relationship between these events is primarily a function of how closely the duration of rainfall compares to the response time of the affected watershed.

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3.2 Storm Runoff and Flood Data

3.2.1 Purpose. Runoff response is the other primary factor, in addition to rainfall, that contributes to the magnitude of a flood. Runoff response is characterized by total runoff volume and the lag time between rainfall and the resulting runoff. The many factors affecting runoff volume and lag time are complex and difficult to quantify with a high level of accuracy. Karst topography, common to southwest Missouri, can have a significant effect on runoff because of the numerous sinkholes, losing streams and springs in these areas. The many factors affecting runoff can be calculated or estimated by the experienced engineer using mathematical runoff models. However, limited accuracy of the available data and the necessity for engineering judgment to determine many of the factors can introduce significant margins of error to the results. The collection of detailed runoff data can improve the accuracy of and confidence in the results of mathematical models and should be completed to the degree feasible with available resources. Historical flood records can be a valuable check of the reasonableness of mathematical models. It is also advisable to compare the results of mathematical models to other equations and methods, including empirically based equations.

3.2.2 Data Collection Methods. An adequate network of flow gauges distributed at key points of interest can collect data both temporally and spatially to allow for quantification of peak flow, total volume and lag time. Specialized gauges can grab water samples at predetermined intervals throughout the storm to provide data for flow-weighted pollutant load calculations. Generally, flow data should be collected in time increments ranging from 5 to 15 minutes, depending on the size of the watershed. Gauges should be placed in areas of study for the purpose of assisting with runoff model calibration. Flow gauges require careful operation and maintenance to ensure quality data are collected; therefore, the number of gauges should be limited based on the availability of personnel and resources. In addition, plans should be made to deploy personnel during and after floods to obtain flood data such as high water marks and flood damage evidence. This information can also be useful when calibrating mathematical runoff models and quantifying flood frequencies.

3.2.3 Classification of Rainfall. With adequate historical runoff data, the frequency of any particular flood event can be quantified with statistical methods. In most watersheds, detailed runoff data are not available for the purpose of making frequency determinations. In the absence of detailed runoff data, flood frequency determinations can be made by applying detailed rainfall data to hydrologic models. Models should be calibrated with runoff data that may be available, such as high water marks.

3.3 Geographical Data

Geographical data useful for developing storm water runoff models should be continually gathered and maintained to improve model accuracy and increase the efficiency of designs. These data include aerial photos, elevation contours, soils, land cover, land use, zoning, karst features, etc.

3.4 Storm Water System Inventory Data

A storm water system inventory should be continually developed and maintained to provide data for more detailed and accurate model development. Storm water inventory data should include physical characteristics for all point features such as inlets and junction boxes, channels, pipes, culverts, bridges, detention basins, and sinkholes.

3.5 Geographic Information System

All data useful for storm water runoff modeling and studies, including rainfall and runoff data, geographical data, and storm water system inventory data, should be developed and maintained within a Geographic Information System (GIS) environment for use in storm water planning studies and design.

4.0 PLANNING

Building upon sound drainage principles and a strong base of watershed data, watershed plans and project priorities can be developed. A brief overview of the City's approach to developing watershed plans and identifying priorities follows. More detailed information on planning is provided in Chapter 3.

4.1 Watershed Assessments and Watershed Plans

4.1.1 Watershed Assessments. Watershed assessments are comprehensive living documents summarizing the current state of a watershed as it relates to storm water runoff. Such assessments should be developed and maintained for watersheds in the Springfield Urban Services Area on a priority basis. The watershed assessment should include a compilation of known data about the watershed in a GIS database format, as well as a bound report comprising maps and text for use by government leaders, engineers, planners, architects, developers, and the general public. These assessments provide information necessary to develop a watershed plan. After a watershed plan has been completed, the watershed assessment should be updated periodically to document progress being made toward the goals and objectives of the watershed plan.

4.1.2 Watershed Plans. Watershed plans should be developed and maintained for each watershed on a priority basis. The goals and objectives of watershed plans should be developed based on the information collected in the watershed assessment, the principles in Section 2, public input, and professional guidance. Characteristics and problems unique to each watershed should be identified and possible alternatives to address each problem presented for public input. Based on the original goals and objectives developed by public input and professional guidance, a plan should be developed to address problems on a priority basis. Watershed plans can then be used to guide future project development and public education and involvement in the watershed as a part of the overall Storm Water Management

Program. Watershed plans must take into account overall program priorities and issues that may exist in the larger, regional watershed.

4.2 Project Priority List

A current list of known storm water problems should be maintained to support the development of watershed plans and a Citywide Project Priority List. Project priority rankings should consider the type, frequency, and severity of flooding, with the highest priority given to health, safety, and welfare issues. More specifically, priority shall be given to cases of significant risk of loss of life and significant risk of flooding of structures and major traffic thoroughfares.

4.3 Project Development, Construction, and Maintenance

As capital improvement needs are identified, efforts should be made to secure funds to design, construct, and maintain storm water improvements. Funding initiatives should be sought at the federal, state, and local levels to meet both short- and long-term program needs. and In accordance with the Citywide Project Priority List, watershed plans, and overall priorities of the Storm Water Management Program, projects will be developed, designed, and constructed as funds become available. Just as public education and involvement is important during development of the watershed master plan, continued communication with the public is important throughout the design and construction phases.

It is imperative that funding initiatives and project designs take into consideration long-term needs. Aspects to consider include mowing, tree maintenance and other vegetation management, sediment removal, and maintenance of structures. Long-term maintenance must be balanced with other objectives such as water quality, flood control, and aesthetics.

5.0 MANAGEMENT OF FLOOD HAZARD AREAS

Proper management of flood hazard areas in a manner that protects the public health, safety, and welfare is a fundamental principle of storm drainage management and planning. The City's approach to minimizing and managing flood hazards is described below.

5.1 National Flood Insurance Program

5.1.1 General. The City is a participant in the National Flood Insurance Program (NFIP), which is administered by the Federal Emergency Management Agency (FEMA). As a participant, the City must maintain and enforce regulations meeting minimum requirements of the NFIP and restricting development in designated flood hazard areas shown on FEMA Flood Insurance Rate Maps (FIRMs). Federal requirements mandate that flood insurance be purchased for mortgaged properties within a FEMA flood hazard area. Because the City is an NFIP participant in good standing, all property owners in the City are able to obtain flood insurance for their property with premiums based on the flood hazard zones shown on the FIRM.

5.1.2 NFIP Minimum Requirements and Additional Requirements for Flood Hazard Areas. The minimum requirements of the NFIP are designed to assess current flood risks of individual properties and develop appropriate flood insurance rates for those properties. Additional or modified requirements are necessary for more comprehensive regulation of developments in or near designated flood hazard areas. NFIP minimum requirements and additional or modified requirements for developments within the City include:

1. FIRM flood elevations are based on watershed development conditions at the time of the Flood Insurance Study (FIS). Depending on the amount of development in the watershed that has occurred since the FIS was completed or that may occur before the next FIS is completed, the FIS may reflect flood elevations that are lower than those for current or future conditions, which poses an unanticipated flood risk if not taken into account. Therefore, designs for development in or near flood hazard areas should anticipate maximum flood elevations from future development in the watershed and take into account flood hazards created since the last study.

2. NFIP regulations permit encroachment into the flood fringe area, provided that the Base Flood Elevation will not increase more than one foot. However, filling of flood fringe areas decreases floodplain storage, which results in a loss of peak flow attenuation, which in turn results in increased flood elevations. This effect of floodplain filling is not accounted for in the FIS determination of Base Flood Elevations and floodway widths. Therefore, fill should be permitted in floodplains only when it is shown there are no resulting impacts on adjacent properties.

3. NFIP studies are typically discontinued at a point where the watershed drainage area is one square mile. Most flood damage occurs upstream of flood hazard areas shown on a FIRM. Therefore, the City will develop and maintain City Flood Hazard Maps up to a drainage area of 40 acres in order to regulate development in or near these areas.

5.2 City Flood Hazard Areas

City Flood Hazard Areas are mapped and the maps are maintained as a part of a comprehensive storm water management program. City Flood Hazard Maps are used to restrict development in or near Flood Hazard Areas. Maps are based on the same flood event as the FEMA FIS Base Flood and are enforceable through the City's floodplain ordinance. As discussed in Section 5.1, the watershed should be assumed to be fully developed based on current or anticipated zoning land uses to account for potential rises in flood elevations in the future. Encroachments into flood hazard areas should occur only when it can be shown that there are no impacts to adjacent properties from loss of floodplain storage and loss of peak flow attenuation. Minimum floor elevations should be set at least one foot higher than the Base Flood Elevation under fully developed watershed conditions based on anticipated zoning and land use and anticipated future developments. City Flood Hazard Areas extend up to a point where the drainage area is approximately 40 acres or as dictated by existing development and specific needs of the area.

5.3 Floodplain Acquisition

The City began the Voluntary Floodplain Acquisition Program after the floods of September 1993. In accordance with the findings of the Citizens' Storm Water Committee, the program is based on the principle of stopping the cycle of flooding, rebuilding, and flooding again. This goal is accomplished through the voluntary acquisition of flood-prone properties within floodplains, sinkholes, and other flood-prone areas after it has been determined that flood protection with storm water improvements alone is not cost effective. Priority is given to buildings in floodways and residential properties with structures that have flooded and have a significant risk of flooding again.

Priority is also given to the acquisition of undeveloped floodplains in strategic locations that provide multipurpose beneficial uses to the community, such as storage for flood control and water quality enhancement, riparian corridors for enhanced habitat, stream protection, open space for linear parks and greenway trails, and water quality protection. Acquisition projects should be carried out in accordance with approved watershed plans. Continuation of the program will significantly reduce flood damages to property within the City, as well as provide multiple additional benefits to the community.

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